

## REPORT DOCUMENTATION PAGE

AFRL-SR-BL-TR-01-

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1. AGENCY USE ONLY (Leave blank) 2. REPORT DATE 3. REPORT PERIOD COVERED  
18 Jan 01 Final: 01 Jul 97 TO 30 Jun 00

0083

4. TITLE AND SUBTITLE CONSTITUTIVE & FAILURE BEHAVIOR OF GRANULAR MATERIALS			5. FUNDING NUMBERS F49620-97-1-0415
6. AUTHOR(S) Dr. M. Zhou			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Georgia Institute Of Technology School Of Mechanical Engineering Atlanta, GA 30332-0405			8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) AFOSR/NA 801 N. Randolph St. Arlington VA 22203			10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION AVAILABILITY STATEMENT Approved for public release: Distribution is unlimited		12b. DISTRIBUTION CODE AIR FORCE OFFICE OF SCIENTIFIC RESEARCH (AFOSR) NOTICE OF TRANSMITTAL DTIC. THIS TECHNICAL REPORT HAS BEEN REVIEWED AND IS APPROVED FOR PUBLIC RELEASE LAW AFR 190-12. DISTRIBUTION IS UNLIMITED.	
13. ABSTRACT (Maximum 200 words) This project provides support for graduate and undergraduate students to conduct research on the dynamic behavior of concrete and mortar over a range of loading rates and under multiaxial states of stress. The objective of this research is to obtain material response data and constitutive characterization for these materials at strain rates of up to 105 S-1, to analyze the evolution of load-carrying and energy absorption capacities, and to understand deformation and failure mechanisms under high pressures and high strain rates, such as fragmentation, comminution and granular flow. The students' investigations have focused on (1) the dynamic response of the "G"-mix concrete under impact conditions, (2) the effect of composite microstructure and aggregate reinforcement on the material stress-carrying capacity, and (3) the failure behavior of mortar under conditions of normal plate impact. Academic achievements for this project have been described in the final report for the parent grant dated December 31, 1999. The activities under the ASSERT grant are summarized here.			
14. SUBJECT TERMS Constitutive & Failure Behavior of Granular Materials			15. NUMBER OF PAGES
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL



**Georgia Institute  
of Technology**

30 AUG 2000

**Office of Sponsored Programs**  
Research Administration, Compliance,  
Training, and Technologies (ReACTT)  
Atlanta, Georgia 30332-0420 U.S.A.  
PHONE 404-894-6944  
FAX 404-894-5285

**August 21, 2000**

**In reply refer to: E-25-A37**

**Capt. Michael T. Chipley  
AFOSR/NA  
110 Duncan Avenue  
Suite B115  
Bolling AFB, DC 20332-8080**

**Subject: AASERT Reporting Form & Final Technical Report  
Project Director(s): Dr. M. Zhou  
Telephone No.: (404)894-3294  
Contract No.: F49620-97-1-0415  
Prime No.: N/A  
"ASSERT: CONSTITUTIVE & FAILURE BEHAVIOR OF  
GRANULAR MATERIALS"  
Period Covered: 7/1/97 – 6/30/00**

The subject report is forwarded in conformance with the contract/gran. specifications.

Should you have any questions or comments regarding this report(s), please contact the Project Director or the undersigned at 404-894-4763.

/tw

**20010221 126**

Sincerely,

**Thelma Woods  
Customer Service Representative**

**Distribution:**

**Addressee: 3 copies  
cc: Ms. Jennifer Bell, AFOSR/PKA  
:ONR-RR**

## Final Report for the Project

**"ASSERT: CONSTITUTIVE AND FAILURE BEHAVIOR OF GRANULAR MATERIALS"**

**Grant Number:** F49620-97-1-0415  
**Period Covered:** July 1, 1997 – June 30, 2000

**Min Zhou**  
**Georgia Institute of Technology**  
**School of Mechanical Engineering**  
**Atlanta, GA 30332-0405**

**Summary:**

This project provides support for graduate and undergraduate students to conduct research on the dynamic behavior of concrete and mortar over a range of loading rates and under multiaxial states of stress. The objective of this research is to obtain material response data and constitutive characterization for these materials at strain rates of up to  $10^5$  s<sup>-1</sup>, to analyze the evolution of load-carrying and energy absorption capacities, and to understand deformation and failure mechanisms under high pressures and high strain rates, such as fragmentation, comminution and granular flow. The students' investigations have focused on (1) the dynamic response of the "G"-mix concrete under impact conditions, (2) the effect of composite microstructure and aggregate reinforcement on the material stress-carrying capacity, and (3) the failure behavior of mortar under conditions of normal plate impact. Academic achievements for this project have been described in the final report for the parent grant dated December 31, 1999. The activities under the ASSERT grant are summarized here.

**Students Supported:**

<u>Graduate Students</u>	<u>Research topic</u>
<u>D. Lucas Grote:</u>	Time-resolved analysis of dynamic response using plate impact Experiments

Mr. Grote received his MS degree in March 1999. Mr. Grote conducted pioneering experiments on the dynamic impact response and failure-wave phenomenon of concrete. He used laser interferometer diagnostics and PVDF internal stress gauge technique to ascertain the existence of the failure waves.

Andrew Keller      Dynamic Failure behavior under uniaxial compression

Mr. Keller received his MS degree in August 2000. HE conducted experimental research on the failure behavior of brittle materials under uniaxial compression conditions. He also analyzed the microscopic failure behavior of materials using scanning electron microscopy.

*Undergraduate Students*

Akwate Watkins  
Patrick Lesher

Dawn Amos  
Kevin Starks

*Responsibilities*

Specimen preparation, machining  
Digitization of concrete microstructure  
ABAQUS installation

Specimen preparation, conduction of experiment  
Design and manufacturing of pressure-shear impact  
target holder

Mr. Watkins is an African American. Miss Amos participated in the 1997 Georgia Tech SURF (Summer Undergraduate Research Fellowship program) while working on this project. The Georgia Tech Material Research Council provided partial support for her work on this project. Mr. Starks designed and manufactured the target holder assembly for pressure-shear impact experiments.

AUGMENTATION AWARDS FOR SCIENCE & ENGINEERING RESEARCH TRAINING (AASERT)  
REPORTING FORM

The Department of Defense (DoD) requires certain information to evaluate the effectiveness of the AASERT Program. By accepting this Grant which bestows the AASERT funds, the Grantee agrees to provide 1) a brief (not to exceed one page) narrative technical report of the research training activities of the AASERT-funded student(s) and 2) the information should be provided to the Government's technical point of contract by each annual anniversary of the AASERT award date.

1. Grantee identification data: (R&T and Grant numbers found on Page 1 of Grant)

a. Georgia Institute of Technology/Georgia Tech Research Corp.  
University Name

b. F49620-97-1-0415  
Grant Number

c. F08671-9701485  
R&T Number

d. Min Zhou  
P.I. Name

e. From: 7/1/97 To: 6/30/00  
AASERT Reporting Period

NOTE: Grant to which AASERT award is attached is referred to hereafter as "Parent Agreement".

2. Total funding of the Parent Agreement and the number of full-time equivalent graduate students (FTEGS) supported by the Parent Agreement during the 12-month period prior to the AASERT award date.

a. Funding: \$ 302,000

b. Number FTEGS: 2

3. Total funding of the Parent Agreement and the number of FTEGS supported by the Parent Agreement during the current 12-month period.

a. Funding: \$ 302,000

b. Number FTEGS: 2

4. Total AASERT funding and the number of FTEGS and undergraduate students (UGS) supported by AASERT funds during the current 12-month reporting period.

a. Funding: \$ 110,000

b. Number FTEGS: 2

c. Number UGS: 4

VERIFICATION STATEMENT: I hereby verify that all students supported by the AASERT award are U.S. Citizens.

Principal Investigator

Date

8/1/00